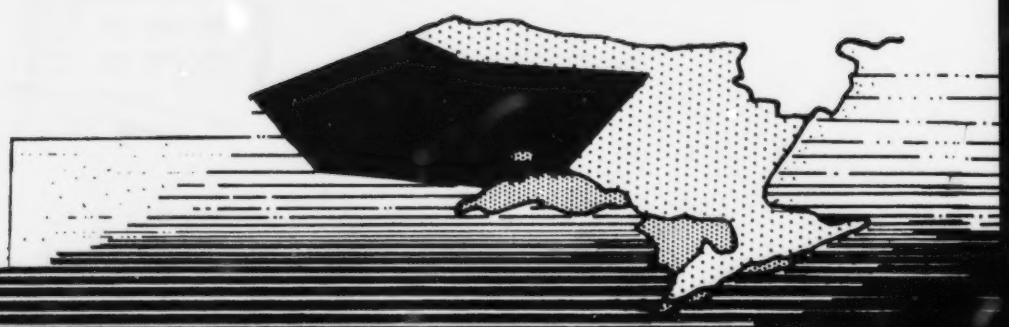

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SPRUCE HEIGHT AND VOLUME GROWTH RESPONSE TO AN AERIAL RELEASE TREATMENT USING 2,4-D ON THREE PLANTATIONS NEAR MANITOUWADGE, ONTARIO

by

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ABSTRACT

Three spruce plantations in the Manitouwadge area of north central Ontario were released from hardwood competition in 1983 with 2,4-D. Three years after release, planted spruce were sampled in treated and untreated areas within each plantation to determine the extent of conifer benefit from the 2,4-D treatment. The relative dominance of the crop trees was determined for each site three years following treatment, and stem analysis was used to measure volume increment and total volumes of selected individual spruce trees.

The 2,4-D treatment provided effective control of brush; relative dominance of spruce crop trees was dramatically improved in the treated areas with up to 97% of the crop trees growing under open-growing conditions as compared to only 37% in the control areas. Released spruce displayed a 2.1 to 3.3 fold increase in total post-treatment volume increment on an individual tree basis. The cumulative height growth for the released spruce during the same post-treatment period showed increases of 1.1 to 1.6 times that of trees on the control blocks.

Several recommendations are presented for the future assessment of growth benefit data when stem analysis is to be employed. Trees to be sampled should be from known pre-treatment dominance and size classes; growth/benefit results are best understood when expressed on a per hectare basis.

Key Words: Chemical tending, crop response, competition, height growth, herbicide, Picea, release, spruce, stem analysis, volume growth, 2,4-D.

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Stem analysis and field collection was completed under the supervision of Kris Sas-Zmudzinski, former Forest Assessment Specialist, North Central Region.

The following individuals provided review of this document for technical accuracy and content:

Dr. R. A. Campbell, Herbicide Specialist, Pest Management Section, Forest Resources Branch, Ministry of Natural Resources, SAULT STE. MARIE.

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Final responsibility for the content and views expressed are those of the authors.

INTRODUCTION

As the natural forests of Ontario are utilized for their supply of pulp and sawlogs, the importance of a reliable and successful forest regeneration program becomes paramount to sustain future fibre demands. In a renewal program which includes the planting of 160 million trees per year, the need for a cost-efficient and silviculturally acceptable method of protecting conifer regeneration from encroaching competitive vegetation is a necessity. Vegetation management is also essential in optimizing the allocation of site resources to the crop trees thereby enhancing the growth and quality of the regeneration.

Forest managers have used 2,4-D to control undesirable woody vegetation for more than 30 years. Phenoxy herbicides are a favoured tending tool due to the minimal environmental impact associated with its forestry use patterns, and the low cost of the chemical and its application. Phenoxy herbicides have consistently proven to be one of the safest forest management tools (Newton 1979; Newton and Dost 1984).

Observations on the short and long-term effectiveness of 2,4-D for releasing conifer crop trees and its impact on other forest components and users have been made by foresters for many years. Numerous studies on the effect of 2,4-D on human and animal health, wildlife habitat, the aquatic environment and some edible plants have shown it to be safe, particularly at the rates used in forestry (Newton and Dost 1984). 2,4-D has been found to be particularly effective in controlling competing vegetation which could cause excessive mortality and suppress the growth of young conifer plantations. There is, however, a gap in the documented information pertaining to the direct benefit and long-term results of herbicides for conifer release.

Operational applications of 2,4-D for conifer release began in the mid-1950's in northern Ontario. As a result of an expanding regeneration program,

a renewed commitment to tending directed at protecting the regeneration investment has since developed. The use of herbicides in Ontario for brush control has increased significantly in 1983 (Figure 1).

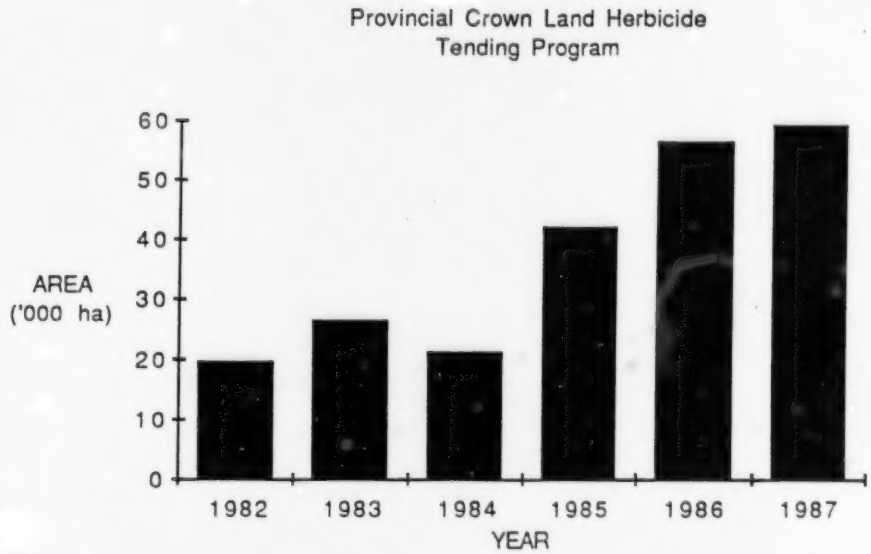

Figure 1. A summary of aerial spraying for tending on crown land in Ontario from 1982-1987.

The principal objective of this study was to study changes in height and volume increments of white and black spruce following an aerial application of 2,4-D for conifer release from brush competition. A secondary objective involved determining the potential usefulness of growth layer analysis involving the T.R.I.M. (tree ring increment measuring system) to these types of investigations. Three sites with different plantation histories were sampled. Crop tree density, relative dominance, total and incremental heights,(post-treatment), and total

and incremental volumes (post-treatment) were measured on trees from both the treatment and control blocks at each location.

STUDY AREAS

In 1983, three plantations were treated with 2,4-D for conifer release on the James River-Marathon Management Unit, Terrace Bay District (85° 50'W, 49° 15'N). A control and treatment block were established at each site following guidelines provided in A. Lehela's and R.A. Campbell's report "Instructions for Assessment of Glyphosate and Forest Management Trials". These plantations were then assessed to determine the herbicidal and silvicultural efficacy of the treatment (Sutton 1985).

Initial data collection in the period 1983 - 1986 was conducted by district staff. Two randomly located transects were established in each of the treatment and control blocks prior to treatment. A total of twenty pairs of sampling quadrats (each 2m X 2m) were randomly located along each of the transects. All planted spruce within each of the quadrats were tagged for future measurement.

Each of the planted spruce were assessed for dominance with respect to the surrounding vegetation, total height (m), and current annual height increment (m) prior to treatment and in the subsequent 1984, 1985 and 1986 growing seasons. Competing vegetation was also enumerated by species, percent cover of the plot area and height class at each of the re-measurement stages (Phillips 1983).

The 1986 stand and site descriptions, three years post treatments, are presented in Tables 1 and 2 respectively.

Table 1. Description of study areas based upon district data.

	Location	Species	Age since planting (years)	Density (stems/ha)	Average total height (1986) (cm)
Snowflake Lake	Control	Black spruce	7	1533	123.6 ± 3.7
	Treatment	Black spruce	7	1720	149.5 ± 3.5
Mann Lake	Control	White spruce	11	1787	170.8 ± 5.1
	Treatment	White spruce	11	1773	164.0 ± 5.0
Janet Lake	Control	White spruce	13	2027	149.2 ± 3.9
	Treatment	White spruce	13	2187	239.6 ± 6.1

METHOD

I. Field Procedure

A detailed assessment of spruce tree growth response was conducted in September, 1986 in each of the Snowflake, Mann and Janet Lake plantations, following procedures developed by Henderson (1986). This data was to supplement that previously collected by the district staff (Phillips 1983) in the intervening three years.

An additional three randomly located transects, 80 metres in length, were established in each of the treatment and control blocks. Five circular sample plots (50 m^2 in area) were then established along each transect at twenty metre intervals creating 15 plots per block. The following information was recorded for each plot:

i) density of planted spruce;

ii) total height of each spruce tree;

iii) current annual height increments for each spruce tree;

(-all crop trees were measured for annual height increment from 1983 to 1986)

Table 2. Site descriptions

Area A. Snowflake Lake	
Soil:	coarse loamy, medium depth, fresh moisture regime, 0 to 10 rockiness, scattered stones
Previous stand:	Po, Bw, Sp, Pj, mixed conifer
Harvested:	1978, cut and skid
Site preparation:	1978, barrels and chains
Planted:	1979, Sb 3 + 0
Total stocking	1984, 71%
Competition:	heavy grass and herbaceous vegetation
Tending:	1983, 2,4-D, 1.68 kg ae/ha, 34 l/ha, Fixed wing, Aug. 15 to 17
Net area:	122 ha
Area B. Mann Lake	
Soil:	coarse loamy, medium depth, fresh moisture regime, 0 to 10 rockiness, scattered stones
Previous stand:	Po, Sp, Bw
Harvested:	1973, cut and skid
Site preparation:	1974, barrels and chains
Planted:	1975, Sw 1 1/2 + 1 1/2
Total stocking:	1980, 73%
Competition:	heavy aspen, cherry, alder
Tending:	1983, 2,4-D, 2.8 kg ae/ha, 34 l/ha, Fixed wing, Aug. 13 to 14
Net area:	176 ha
Area C. Janet Lake	
Soil:	coarse loamy, deep, fresh moisture regime, 0 to 10 rockiness, frequent stoniness
Previous stand:	Po, Sp, Bw
Harvested:	1971, cut and skid
Site preparation:	1972, barrels and chains
Planted:	1973, Sw 3 + 0
Total stocking:	1978, 82%
Competition:	heavy aspen, pin cherry, Bw
Tending:	1983, 2,4-D, 3.37 kg ae/ha, 34 l/ha, Fixed wing, Aug. 20 to 23
Net area:	174 ha

iv) relative dominance of spruce trees in relation to surrounding vegetation (Henderson 1986).

Relative Dominance

The relative dominance of each spruce tree was described as suppressed, intermediate or open-growing in relation to the surrounding competing vegetation on the respective plot following criteria established by Henderson (1986). The criteria for this classification were:

Open-growing - the height of the competing vegetation within a 1m radius of the crop tree is below the top of the crop tree;

Intermediate - the competing vegetation within a 1m radius of the crop tree is shading and is between 0 to 30 cm taller than the crop tree.

Suppressed - the competition within a 1m radius of the crop tree is shading and is at least 30 cm taller than the crop tree;

Competing species which were taller than the spruce crop tree but which were not directly shading the tree were not considered in the determination of dominance class.

II. Growth Layer Analysis

Randomly selected spruce trees from the plots on each of the treatment and control blocks were destructively sampled to permit examination of the influence of release on individual tree volume production. The number of trees sampled within each dominance class varied in proportion to the relative occurrence of that dominance class within the respective treatment and control blocks (Figure 2). The spruce selected for destructive sampling had to be free of physical damage, incidence of disease and growing under favourable micro-site

conditions. Trees were felled, labelled and returned to Thunder Bay for detailed growth layer analysis.

Each destructively sampled spruce was sectioned along the bole. Discs were collected according to a pre-determined sampling sequence (Table 3). The sampling sequence was determined by the total height of the crop tree at time of sampling.

Each disc was measured on the Tree Ring Increment Measuring System (TRIM). Ring widths were measured for two radii (north and south) and an average ring width sequence was determined. The tracking accuracy of the TRIM system is 0.01 mm.

Table 3. Growth Layer Analysis Sequence

Sequence 1 *Ht=0 to 1m	Sequence 2 *Ht=1.1 to 1.5m	Sequence 3 *Ht=1.6 to 2.0m	Sequence 4 *Ht>2.1m
0 cm	0 cm	9 cm	0 cm
10 cm	40 cm	40 cm	40 cm
every 10 cm	50 cm	70 cm	70 cm
to top	every 10 cm	80 cm	100 cm
	to top	every 10 cm	130 cm
		to top	140 cm
			every 10 cm
			to top

* Total spruce tree height at time of sampling.

RESULTS

I. Relative Dominance

Each of the three treatment blocks had exhibited a shift in the relative dominance of spruce trees compared to that encountered on the corresponding control blocks. Three years after spraying, 75 percent to 97 percent of planted spruce in the treatment block of each of the three plantations were open-growing. In contrast, the percentage of open-growing spruce on the control blocks ranged from 14 percent to 35 percent. As might be expected, suppressed crop trees constituted from three percent to 15 percent of the released population while 33 percent to 55 percent of the planted spruce in the control blocks remained suppressed (Figure 2).

II. Influence of Herbicide Release Treatment on Spruce Tree Volume

The randomly selected spruce from the treatment and control blocks of each plantation were destructively sampled and subjected to growth layer analysis. This procedure provided data on the current annual volume and cumulative volume growth for each tree backdated to their first year of growth.

Mean 1983 pre-treatment total volumes for spruce in the treatment and control blocks of each plantation were compared using an unpaired 't' test approximation. The analyses indicated that in general, the average individual tree pre-treatment cumulative volume (1983) of spruce growing on the treatment blocks was significantly greater than that for spruce on the control (Table 4).

The exception to this occurred at Mann Lake where there was no significant difference in the mean pre-treatment cumulative volume for spruce on the treatment and control blocks.

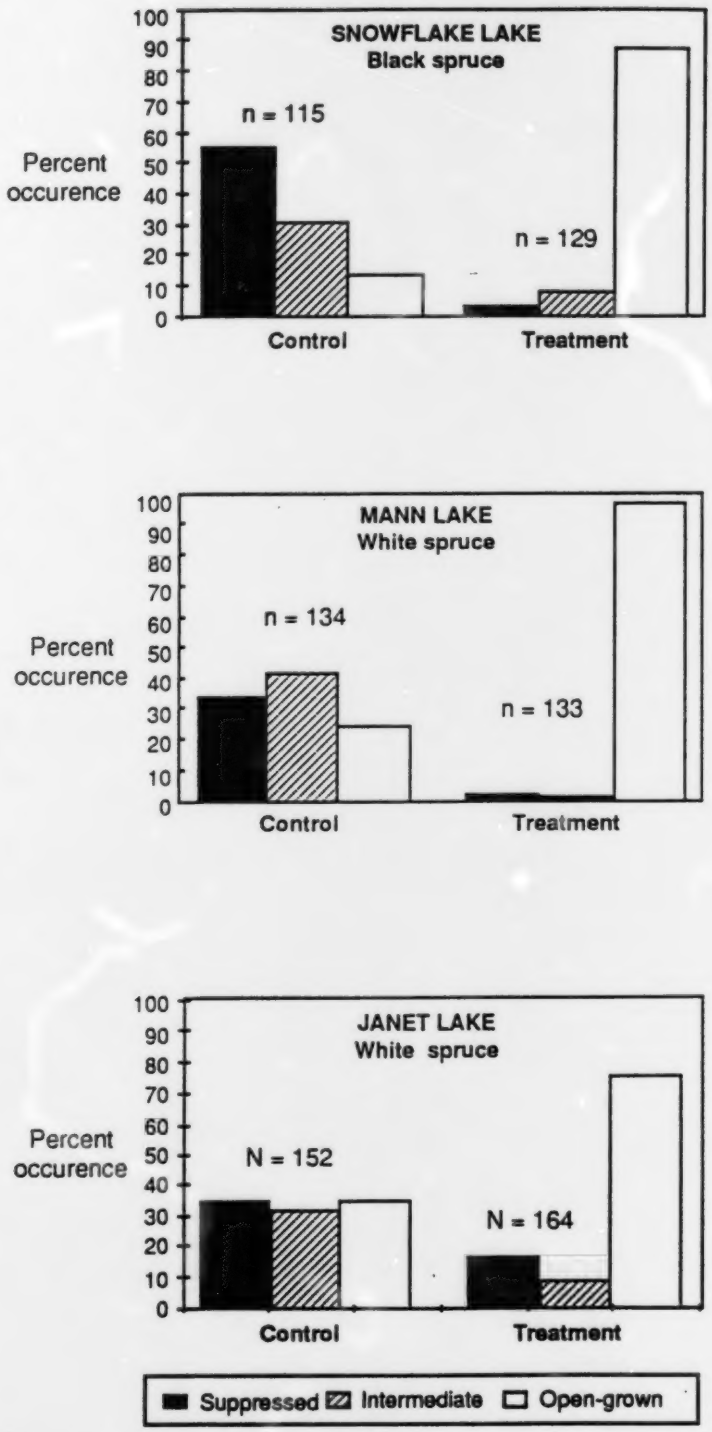

Figure 2. Relative dominance of spruce crop trees under control and 2,4-D treated conditions three years after tending.

Table 4. Mean 1983 pre-treatment volume of spruce trees destructively sampled from the control and treatment blocks in each of the three plantations.

Location	Dominance class	Treatment	Sample size	Mean (cm^3)	Range (cm^3)
A. Snowflake Lake	All	Control	22	0.08 ± 0.01 a	0.01 - 0.20
		Treatment	11	0.26 ± 0.06 b	0.03 - 0.64
B. Mann Lake	All	Control	19	0.79 ± 0.32 a	0.03 - 5.84
		Treatment	12	0.75 ± 0.22 a	0.05 - 2.04
C. Janet Lake	All	Control	18	1.85 ± 0.41 a	0.06 - 5.83
		Treatment	12	3.55 ± 0.67 b	0.48 - 7.14

Note: Treatment response variables followed by different letters differ significantly at the p=0.10 level within dominance class and plantation.

Table 5. Mean 1986 post-treatment volume of spruce trees destructively sampled from the control and treatment blocks in each of the three plantations.

Location	Dominance class	Treatment	Sample size	Mean (cm^3)	Range (cm^3)
A. Snowflake Lake	All	Control	22	1.26 ± 0.40 a	0.07 - 1.68
		Treatment	11	3.62 ± 0.63 b	0.78 - 6.65
B. Mann Lake	All	Control	19	3.41 ± 1.13 a	0.06 - 19.82
		Treatment	12	5.72 ± 1.64 b	0.20 - 17.00
C. Janet Lake	All	Control	18	5.27 ± 1.15 a	0.45 - 18.11
		Treatment	12	13.99 ± 2.41 b	3.40 - 24.39

Note: Treatment response variables followed by different letters differ significantly at the p=0.10 level within dominance class and plantation.

Given that the trees were randomly selected, the significant pre-treatment difference in volume would suggest site differences between the treatment and control areas.

Cannell et al. (1984) has stated that even on uniform sites, the genetic, micro-site, stock and planting quality (Burdett et al. 1984), as well as chance factors can often be equally important as competition in determining the performance of individual seedlings.

No significant differences between treatment means were detected when the data were stratified according to post-treatment dominance class. Unfortunately, the sample size was not large enough to determine if there was any significant relationships between post-treatment dominance class and post-treatment volume growth. The small sample sizes at a level of $\alpha = 0.10$ will not allow us to detect small but truly significant differences.

Table 5 presents the mean 1986 post-treatment total volumes for the same spruce trees, two complete growing seasons following the release treatment. The analyses again indicated that, in general, the average post-treatment total volume (1986) was significantly greater for the spruce growing on the treatment blocks. Given the initial significant pre-treatment differences in total volume between trees on the treatment and control blocks of Snowflake and Janet Lakes, respectively, it cannot be concluded that this latter difference is due solely to the release treatment.

Differences in the mean total volume increment during period 1983 - 1986, (Figure 3) indicated that released spruce produced 2 to 3 times more volume as non-released spruce crop trees (average of all dominance classes). Again, since the density of spruce is similar in both the treatment and control blocks of the Snowflake and Janet Lake sites, and given initial significant pre-

treatment differences in total volume at Janet and Snowflake Lake, the differences in the subsequent volume increment observed for these two areas may be only partially attributable to the release treatment.

III. Influence of Herbicide Release Treatment on Spruce Tree Height

A comparison of the mean total pre-treatment heights of spruce indicated that no significant difference existed between treatment and control blocks in each of the three plantations (Table 6). Subsequent stratification of the data according to dominance class did not detect specific significant differences in total pre-treatment heights, possibly because of sample sizes for some dominance classes within the treatment block.

Three years after release, spruce trees from the Janet Lake and Snowflake Lake block were significantly taller than those of the control (Table 7). Spruce growing on the Mann Lake treatment block were not significantly taller than those on the control; possibly due to increased frost damage to the buds and terminal leader which followed the removal of the broad-leaved vegetation.

As shown in Figure 4, spruce growing on the treatment blocks displayed between a 110 to 160 percent average increase in cumulative height increment for the period 1983 to 1986, compared to that experienced by spruce under control conditions (Figure 4). While the differences in cumulative height increment at Janet and Snowflake Lakes contributed to significant differences in the average total post-treatment heights being detected, the same cannot be said of the released spruce at Mann Lake.

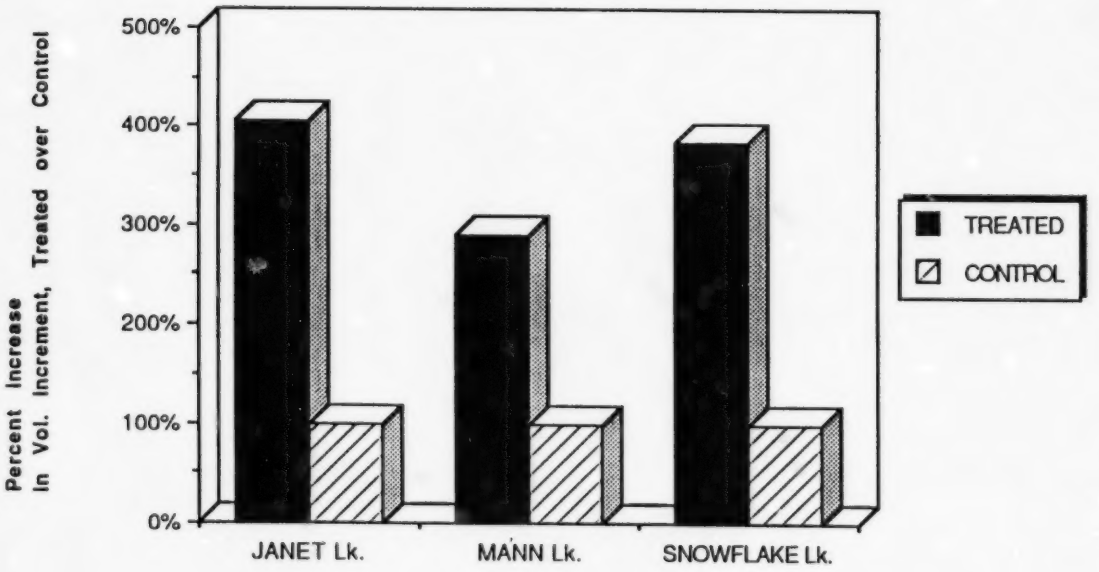

Figure 3. Mean volume increment increase for tended spruce in three Manitouwadge plantations between 1983 and 1986.

Table 6. Mean 1983 pre-treatment total height of spruce trees measured from the control and treatment blocks in each of the three plantations stratified by pre-treatment dominance class.

Location	Dominance Class	Treatment	Sample Size	Mean (cm)	Range (cm)
A. Snowflake Lake	All	Control	147	16.7 ± 0.6 a	3.0 - 34.0
		Treatment	150	21.4 ± 0.8 a	3.0 - 45.0
	Open-growing	Control	13	20.5 ± 1.4 a	11.0 - 33.0
		Treatment	133	22.1 ± 0.9 a	3.0 - 45.0
	Intermediate	Control	49	18.9 ± 1.2 a	8.0 - 34.0
		Treatment	11	18.6 ± 1.9 a	3.0 - 24.0
	Suppressed	Control	81	14.4 ± 0.8 a	3.0 - 30.0
		Treatment	6	8.8 ± 1.8 a	4.0 - 12.0
B. Mann Lake	All	Control	166	26.3 ± 0.9 a	7.0 - 62.0
		Treatment	154	21.6 ± 0.8 a	3.0 - 47.0
	Open-growing	Control	33	34.7 ± 1.9 a	14.0 - 62.0
		Treatment	149	21.9 ± 0.8 b	3.0 - 47.0
	Intermediate	Control	89	27.3 ± 1.1 a	13.0 - 50.0
		Treatment	2	17.5 ± 3.5 a	14.0 - 21.0
	Suppressed	Control	44	18.7 ± 1.2 a	7.0 - 44.0
		Treatment	3	11.7 ± 1.8 a	9.0 - 15.0
C. Janet Lake	All	Control	227	18.8 ± 0.6 a	3.0 - 55.0
		Treatment	80	25.8 ± 0.9 a	3.0 - 57.0
	Open-growing	Control	119	26.8 ± 0.9 a	7.0 - 55.0
		Treatment	49	23.4 ± 1.4 a	5.0 - 57.0
	Intermediate	Control	55	19.6 ± 0.9 a	8.0 - 39.0
		Treatment	18	26.8 ± 0.3 a	7.0 - 55.0
	Suppressed	Control	53	13.8 ± 0.7 a	3.0 - 27.0
		Treatment	13	15.2 ± 2.8 a	3.0 - 37.0

Note: Treatment response variables followed by different letters differ significantly at the p=0.10 level within a dominance class and plantation.

Table 7. Mean 1986 post-treatment total heights of spruce trees measured in the control and treatment blocks stratified by pre-treatment dominance class.

Location	Dominance Class	Treatment	Sample Size	Mean (cm)	Range (cm)
A. Snowflake Lake	All	Control	147	123.0 ± 3.7 a	52.0 - 240.0
		Treatment	150	149.0 ± 3.5 b	66.0 - 250.0
	Open-growing	Control	13	145.0 ± 9.0 a	90.0 - 200.0
		Treatment	133	153.0 ± 3.7 b	66.0 - 250.0
	Intermediate	Control	49	142.0 ± 6.9 a	80.0 - 240.0
		Treatment	11	128.0 ± 7.4 a	77.0 - 160.0
	Suppressed	Control	81	107.0 ± 4.0 a	52.0 - 190.0
		Treatment	6	100.0 ± 5.4 a	85.0 - 110.0
B. Mann Lake	All	Control	166	170.0 ± 5.1 a	70.0 - 334.0
		Treatment	154	164.0 ± 5.0 a	69.0 - 350.0
	Open-growing	Control	33	196.0 ± 8.5 a	138.0 - 334.0
		Treatment	149	173.0 ± 5.1 b	73.0 - 350.0
	Intermediate	Control	89	182.0 ± 7.2 a	95.0 - 296.0
		Treatment	2	114.0 ± 9.0 b	105.0 - 123.0
	Suppressed	Control	44	116.0 ± 5.5 a	70.0 - 232.0
		Treatment	3	71.7 ± 2.2 b	69.0 - 76.0
C. Janet Lake	All	Control	227	149.0 ± 3.9 a	60.0 - 300.0
		Treatment	80	239.0 ± 6.0 b	72.0 - 420.0
	Open-growing	Control	119	189.0 ± 7.5 a	104.0 - 300.0
		Treatment	49	247.0 ± 6.7 b	72.0 - 420.0
	Intermediate	Control	55	154.0 ± 3.4 a	104.0 - 201.0
		Treatment	18	245.0 ± 13.7 b	165.0 - 358.0
	Suppressed	Control	53	107.0 ± 3.5 a	60.0 - 190.0
		Treatment	13	160.0 ± 14.8 b	100.0 - 285.0

Note: Treatment response variables followed by different letters differ significantly at the p=0.10 level within dominance class and plantation.

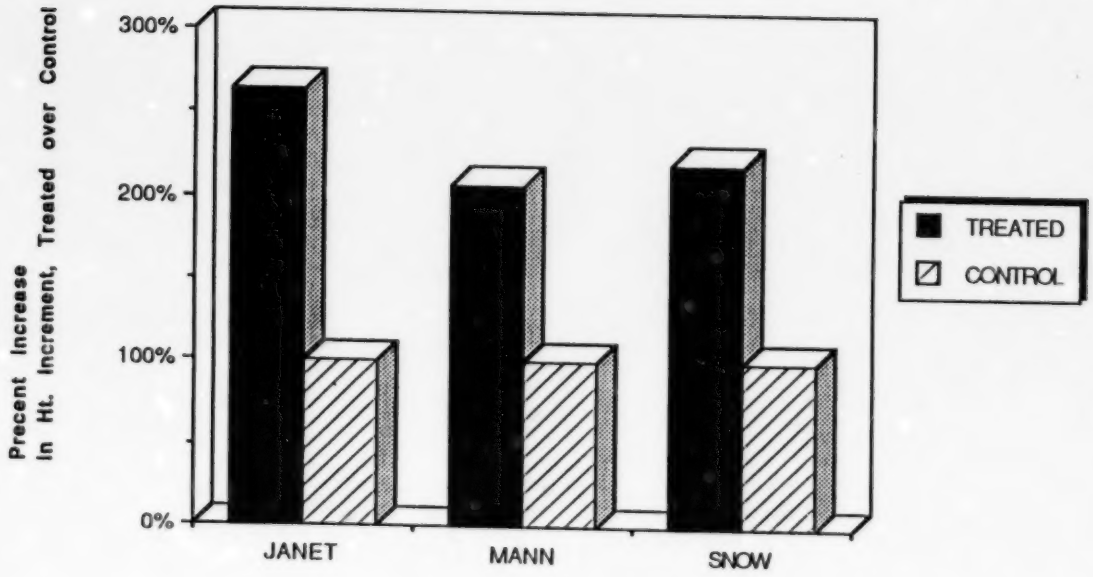

Figure 4. Mean height increment for tended spruce in each of the three Manitouwadge plantations, between 1983 and 1986.

DISCUSSION AND CONCLUSIONS

Minimal differences in spruce tree density between treatment and control blocks in each of the three plantations were found. Although quantitative data on changes in competition density were not calculated, qualitative observations clearly showed the success of the 2,4-D treatment in controlling competing vegetation.

The relative proportion of spruce trees on the treatment blocks occurring in the open-growing dominance class also illustrates the beneficial effect of the release treatment. In the blocks not treated with herbicide, there were only 14 to 35 percent of the spruce trees occurring under "open-growing" conditions. In contrast, over 75 percent of the spruce trees in the treatment blocks were growing competition free. Based upon observations of the amount of undesirable post-treatment vegetation growing around the spruce trees, competition will not pose a serious problem in the future. An aerial spray treatment of 2,4-D for weed control improved the relative dominance position of the spruce trees.

The post-treatment response measured as cumulative post-treatment volume increment should also be considered a measure of success. Spruce growing on the treatment blocks produced an average of 2.1 to 3.3 times more volume than the spruce growing under competition in the control blocks during the same 3-year period. This finding conforms to the trends mentioned by Perala (1982). Unfortunately we are unable to confirm whether this response was solely due to release or whether the trees on the treatment blocks were in a preferential growing environment prior to release.

The difference in total height of spruce trees growing in the treatment blocks was statistically greater for two of the three plantations. Total height increase ranged from 20 percent to 64 percent in the treatment blocks of

Snowflake and Janet Lakes, both of which were unaffected by frost damage. The post-treatment cumulative height increment for the treated spruce trees was 110 percent to 160 percent greater than that of the controls for the same three year period. An exception to this occurred in the Mann Lake area where frost damage imposed a negative impact on the height increment of treated trees.

The results of this study lead to the conclusion that the growth benefit from 2,4-D release is not easily detected or manifested in solely increased height or volume growth. The sensitivity of such variables to changing competitive stress may not be great enough during the establishment phase of plantation development to make any one variable a reliable measure of growth response. A high variability within the small sample size of the destructively analyzed trees, and the associated difficulty in detecting significant differences between treatment means, strongly suggests that using a single criterion of height or diameter as a measure of release response is questionable. Similar conclusions have been made in previous studies. Day (1974) stated that the measurement of height growth of conifer regeneration in Kapuskasing did not indicate that there had been a response to release from brush competition. Only a slight positive effect on the height increment of the crop trees was reported by Verheggen (1982).

The few studies which have considered volume increment indicate that volume, not height, is the best measure of response (Lehela 1976; Perala 1982). Documented literature supports the hypothesis that volume growth is more sensitive to environmental factors than height growth (Mader 1963; Van Eck and Whiteside 1963; Kramer and Koslowski 1960).

The recently developed Tree Ring Increment Measuring System (T.R.I.M.) shows some potential as a tool for quantifying growth response. However, the

usefulness of the data still depends upon the sampling strategy; T.R.I.M. will track the growth progression of a tree with time, but it cannot describe the conditions under which that growth occurred. T.R.I.M. can be time-consuming and requires destructive sampling and laboratory analysis. A practical, cost-efficient and easily applied procedure for assessing changes in volume increment will be required by field staff to assess volume growth benefit and silvicultural efficacy of plantation release using herbicides.

T.R.I.M. sampling of individual trees randomly selected from the existing post-treatment dominance classes does not permit separation of growth response due to release treatment from that of other confounding factors such as soil/site, micro-site or stock quality. Nor will growth layer analysis by itself allow post-priori assignments of sampled trees to pre-treatment dominance classes. Plot establishment must precede treatment application; pre-treatment plot/stand conditions need to be recorded. Finally, growth response may be best expressed on a fixed area basis rather than by average individual tree; T.R.I.M. analysis can provide this information on an aggregated per hectare basis providing that the trees to be destructively sampled are selected prior to treatment.

Apparent and large gains in total individual tree volume, and by inference, also in increment, were realized on spruce trees in the treated areas. These gains should improve the ability of the crop tree to compete successfully with other plant species, and also increase the potential economic value of the stand. Increased volume increment can reduce the stand rotation age and provide increased volume per unit area. Likewise, increased survival rates often associated with release treatments will also contribute to an increased volume

per unit area by improving the stocking and utilization of growing space. Both of these factors result in increased return on investment per hectare.

There is little evidence at the present time to state that these plantations will or can maintain the same growth rate for many years past the initial release treatment. In fact, it is not likely that the growth rates would differ between treatments once they are growing free of competition, assuming all other factors to be equal. This would not, however, change the fact that probable gains in individual tree volume and increased survival following release, were realized at an early stage, will contribute to reduced rotation ages and greater total merchantable volume per hectare

2,4-D controls aspen competition with varied degrees of success, and is effective in controlling brush species such as speckled alder, beaked hazel, pin cherry and white birch. Interestingly another herbicide frequently used for conifer release, glyphosate is not as effective at controlling hazel, pin cherry, and white birch, although it is very effective in controlling aspen, raspberry, and grass. To cover the full spectrum of major competing species 2,4-D remains a valuable tool for vegetation management.

RECOMMENDATIONS

1. Volume response for purposes of identifying growth benefit is most meaningful when expressed on a per hectare basis and not on an individual tree basis. This will necessitate the use of fixed area plots; the preparation of local stand tables and the possible destructive sampling from a priori-assigned dominance and size classes.

2. A preliminary survey should be conducted to determine site variability. Stocking data can be easily collected at this time.

3. Plots should be randomly established throughout the designated control and treatment blocks prior to the release treatment being applied. Sufficient numbers of plots will be required to estimate the variable being observed within a ten percent standard error of the mean.

4. Plots located in juvenile stands where crown closure has yet to occur should each be 50m (Henderson 1986). All stems should be recorded measured and tagged for future sampling. Post-treatment measurement of crop trees on those plots will be required to quantify growth responses, if any. Each crop tree must also be assigned to a pre-treatment dominance class for purposes of future comparison.

5. Forslund's (1986) formula provides a reliable, accurate and efficient procedure for calculating gross merchantable volume for individual crop trees within the plots (both pre-treatment and post-treatment).

6. Growth layer analysis using T.R.I.M. is recommended for determining changes in annual volume growth increment and not just total volume measurements because of the relatively high cost of analysis. Growth layer analysis should not be used if total height, total volume and annual height increments are the only response variables being measured.

7. Growth layer analysis should involve trees sampled from known pre-treatment dominance/size classes.

8. The observed growth response following a release treatment is dependant upon many factors including the time period since release occurred. This will be site, species and genotype dependant. Delayed growth response following treatment must be anticipated; this aspect of growth benefit needs to be quantified and investigated further.

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